FGCC

Test and Evaluation of Total Station Instruments

FGCC Report: FGCC-IS-87-1

Stephen R. DeLoach

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TEST AND EVALUATION OF TOTAL STATION INSTRUMENTS

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ABSTRACT. Total station instruments, which combine an electronic distance measuring instrument and a theodolite, have been widely accepted by the surveying community to perform geodetic surveys as well as other types of measurements. In response to this new technology, the Federal Geodetic Control Committee (FGCC) tested the following total station instruments: Geodimeter 142, Kern E2, Lietz SET 3, Nikon DTM-1, Topcon ET-1, and Wild T2000. The objective was to determine the relationship between the capabilities of the new instruments and the specifications for geodetic surveys as given in the FGCC publication Standards and Specifications for Geodetic Control Networks. Field observations were made using each instrument between November 1985 and July 1986. A thorough evaluation of these data indicates that these instruments are fully capable of performing geodetic quality horizontal surveys when proper procedures are followed. Establishing geodetic quality elevations was less successful; however, it may be possible to develop new techniques to take advantage of this potential.

INTRODUCTION

Recent advances in technology have created many new tools for the surveyor. One of these, the total station, has been widely accepted by the surveying community to perform various types of measurements including geodetic surveys.

Essentially, a total station is a combination of two instruments: an electronic distance measuring instrument (EDMI) and a theodolite. This arrangement creates a convenient field unit with actual operational characteristics similar to the older style instruments. Major changes warranting attention are the increased capabilities built into the new units as a result of advances in electronic technology.

In response to this emerging technology the FGCC began testing various total station instruments. The objective was to determine the relationship between the capabilities of the new instruments and the specifications for geodetic surveys as given in the FGCC publication Standards and Specifications for Geodetic Control Networks (1984). This report describes instrument testing and subsequent data analysis.

The published specifications are divided into the following sections: Network Geometry, Instrumentation, Calibration Procedures, Field Procedures, and Office Procedures. Covered under these categories are triangulation, traversing, and geodetic leveling. This evaluation deals only with those items that are dependent on an instrument's capabilities. For example, astronomic azimuth spacing, which is not dependent on a particular instrument, was not considered. Six instruments were tested:

Geodimeter	142
Kern	E2/DM503
Lietz	SET 3
Nikon	DTM-1
Topcon	ET-1
Wild	T2000/DI5

DESCRIPTION OF TEST

Equipment tests were conducted by the Instrument and Equipment Section of the National Geodetic Survey (NGS) at its facility in Corbin, Virginia. Testing, which consisted of the phases discussed below, took place between November 1985 and July 1986. The actual sequence of tests was dictated by weather and available personnel.

Instrument Familiarization

The primary person performing these tests and the principal instrument operator spent one day becoming familiar with the functions and characteristics of a given instrument. Because various functions differed from instrument to instrument, this initial procedure determined the modifications required in data collection to accommodate a particular instrument.

Sensitivity Tests

Prior to performing the field measurements each instrument was bench tested to check for level vial sensitivity, horizontal and vertical collimation error, cross hair linearity, and automatic compensator sensitivity. The purpose of these tests was to verify that the instrument was operating to the manufacturer's specifications. These tests were used as prequalifiers prior to actual field testing. Therefore, the results are not published. An instrument was field tested only after the sensitivity testing showed it performed to acceptable standards.

These tests proved valuable to the overall project because several instruments were returned to the manufacturers for adjustments prior to field testing.

Automatic Compensator Sensitivity

This test was performed to check the function of the instrument's automatic compensator. It was performed on a test instrument, called a Level Trier, developed by NGS personnel at Corbin.

The Level Trier consists of a platform mounted on a beam hinged at one end and supported by a very finely threaded screw at the other end. The screw has a dial attached to it which is graduated such that one division of the dial, from the fixed index, tilts the platform 1" (arc second). Thus, the platform may be tilted through an arc of several minutes very accurately and the vertical angle correction of the instrument may be conveniently checked.

The test is performed by setting the Level Trier dial to zero and carefully leveling the instrument on the platform. The telescope is aligned with the beam and the vertical angle set to 90°. Then the Level Trier is tilted 10" by turning the dial and the vertical angle is recorded. This is repeated until the instrument has been tilted 1' (arc minute). Then the vertical angle is changed 10° and the instrument is tilted through one more minute of arc in 10" increments. Now the Level Trier is reset, the angle is changed 10°, and the sequence is repeated. The observed change in the vertical angle should correspond to the amount of tilt set into the Level Trier. The range of vertical angles checked was limited from 45° above the horizon to 45° below the horizon, this being considered the most commonly used range.

Determination of Sensitivity and Level Vial Value

The purpose of this test was to determine the sensitivity and value in arc seconds of the level vial on each of the instruments. The level tube used in surveying instruments is a glass vial with the inside ground barrel-shaped, so that a longitudinal line on its inner surface is the arc of a circle. The tube is nearly filled with a 50-50 mixture of sulfuric ether and alcohol. The remaining space is occupied by a bubble of air that takes up a location at the high point in the tube. The tube is usually graduated in both directions from the middle; thus, by observation of the ends of the bubble it may be centered, or its center brought to the midpoint of the tube.

A longitudinal line intersecting the curved inside surface of the bubble at its upper midpoint is called the "axis of the level tube." When the bubble is centered, the axis of the level tube is horizontal.

If the radius of the circle to which the inner chamber of the level tube is ground is large, a small vertical movement at one end of the tube will cause a large displacement of the bubble; if the radius is small, the displacement will be small. Thus the radius of the tube is a measure of its sensitivity. The sensitivity is generally expressed in the number of seconds of arc of the central angle, for one division marked on the tube. For most instruments the length of a division is 2 mm. The sensitivity expressed in seconds of arc is not a definite measure unless the spacing of graduations is known.

This test was also performed on the Level Trier. Basically, the level bubble was moved through the range of its scale, and readings were taken simultaneously on the bubble and Level Trier micrometer. The amount which each end of the bubble moves for each new setting of the micrometer is computed, "difference, left and right." To detect irregularities in the level vial, values were computed by dividing the interval between successive micrometer readings by the number of divisions the bubble moves between observations. The level value for each set of observations was derived by summing successively computed values and dividing by the number of computed values. The final value was determined by summing the level values from each set of observations and dividing by the number of sets.

Horizontal and Vertical Collimation Check

Each instrument was tested for horizontal and vertical collimation errors. The instrument was adjusted so that there was no parallax in the telescope for the individual observer performing the test. After careful leveling a pointing was made in the direct position at the infinity target in a visual collimator. The instrument was reversed and pointed at the same target. Both horizontal angles were recorded. This procedure was repeated six times. The sum of the mean direct and reverse pointing should equal 360° 00' 00". If the collimation was greater than 10", appropriate adjustments to the cross hairs were made.

To check for vertical collimation, the instrument was again carefully leveled and pointed at the infinity target in a visual collimator. The appropriate calculations were performed and any required adjustments made to ensure a minimum collimation error.

Cross hair Linearity

This test was done to ascertain that the vertical and horizontal parts of the cross hair were truly vertical and horizontal, respectively. This check was performed by simply pointing the vertical cross hair at a well-defined point and observing that point while the telescope was moved vertically through the field of view. The same was done with the horizontal cross hair. Any observed deviation was corrected by cross hair adjustment.

EDMI Calibration

The electronic distance measuring instrument (EDMI) test was performed on the Corbin Calibration Base line in accordance with *NOAA Technical Memorandum NOS NGS-10*, "Use of calibration base lines" (1980). The collected data were reduced and a least squares adjustment performed. This adjustment yielded the following information:

1. Combined atmospheric and instrument scale error.
2. Combined reflector and EDMI constant.
3. Variance of unit weight, based on the instrument manufacturer's stated accuracy.
4. Standard error of scale error determination.
5. Standard error of EDMI and reflector constant.

Appendix A contains published values for the Corbin Calibration Base Line.

Calibration Base Line Procedures

Each station in the base line has a permanent instrument stand. Prior to occupying each station the top of the stand was collimated over the mark using a Wild Model NL optical plummet.

Observations were taken to a target-reflector combination, mounted on a 15 cm offset bar. A complete set of observations consisted of 10 readings to the +15 and -15 cm positions and 20 readings to the 0 position.

Air temperatures were measured at both ends of the line being observed. The measuring devices were digital aspirated thermistors having an accuracy of ±0.1°C. The temperatures were measured at the beginning and end of each bar position. The sensor probe was elevated at least 3 m above the ground and was kept in the shade. The thermistors were periodically checked with thermometers calibrated by the National Bureau of Standards in Gaithersburg, Maryland. Along with temperature, barometric pressure and water vapor content of the atmosphere were measured before and after each bar position at each end of the line. Barometric pressure was measured with Wallace and Tiernan barometers having an accuracy of ±0.5 mm of mercury. The barometers were periodically checked with a laboratory mercury column. Atmospheric water vapor content was measured with a Bendix aspirated psycrometer.

All data from the calibration base line were recorded on a Radio Shack Model 100 portable computer. Appendix B lists a sample output of the data collector.

Total Function Test

This test was performed by occupying four points on the Corbin test quad. Each station has a 1.3 m stand firmly anchored in the ground and topped by a specially fabricated adjustable tribrach. Before occupying each station, the adjustable tribrach was collimated using a Wild NL optical plummet. A special attachment was fabricated to measure the height above the mark of each tribrach to +0.1 mm. This height was also measured each time the station was occupied. Next, a Wild GDF6 type tribrach was fastened to the adjustable tribrach on the stand and carefully leveled with a specially adapted, and calibrated, level vial.

The targets used were designed with a retro-reflector at the center of a metal plate, which had one vertical and one horizontal stripe to permit sighting the center of the reflector. Two more horizontal stripes were placed above and below the reflector at distances corresponding to the offset between the optical axis and EDMI axis of each instrument that was not made coaxial. White stripes on a black background were chosen for maximum contrast and ease of pointing.

Each station of the quad was occupied with each instrument three times, each time with a different observer. Each observer measured horizontal directions using 16 plate positions (either electronic or mechanical) with direct and reverse pointings. Sixteen sets of zenith distances, or vertical angles, were observed in circle left and circle right. Slope distances were also measured 16 times. The difference of elevation, or delta h function, was also observed and recorded. Temperature, barometric pressure, and water vapor content were measured for each set of observations. The instrument was always shaded by an umbrella.

Data Collection and Processing Systems

Owing to the amount of data accumulated in testing the total station instruments, the observing, recording, checking, and reduction of the measurements were a lengthy process. To reduce the time involved, a data collection and processing system was developed.

The system hardware consists of a Radio Shack Model 100 portable computer, a portable 3-1/2 inch floppy disc drive, and printer. Software for both recording measurements and processing data was developed and written on the Model 100 by Mr. Orland Murray of the NGS Instrument and Equipment Section.

The Model 100 and data recorder program functioned as an electronic field book for all observations on the test quad. All instrument information (manufacturer, type, serial number, etc.), standpoint and forepoint information (name, height of tripod, height of instrument, etc.), and observed measurements were entered into the computer.

The program provides thorough error checking at the point of entry of the data to avoid blunders and minimize later editing. All entries are prompted for and easily corrected if miskeyed. As observations proceed, information such as horizontal and vertical collimation is displayed to allow the user to monitor the data and detect any discrepancies in the observations. The program also provides ample opportunity for entering comments during observations.

Data sets are organized by unique file name and consist of 16 direct and reverse positions. At each position horizontal directions, zenith distances, EDMI slope distances, and differences of elevation are recorded. Only direct EDMI distance measurements are entered in cases where reverse measurements were not possible due to instrument configuration. Each file also contains information about the instrument, standpoint, forepoints observed, and any other information pertinent to that set of observations.

Each of the data reduction programs performs the following:

1. Reads the respective data from the observation files produced by the data collection program.

2. Reduces data according to standard NGS procedures (means direct and reverse, computes corrected slope distances, etc.)

3. Prints a hard-copy field book of all the raw data and reductions.

4. Computes and prints either an abstract or summary of reduced data, which includes a mean and standard deviation of a single observation, except for differences of elevations shown on page 43.

Appendix B contains examples of the computer printouts.

No manipulation of the data is performed other than standard NGS reductions for field observations. The means and standard deviations are not held to any tolerances or rejection limits. Data were edited to eliminate obvious errors. These show up readily on the abstracts or summaries. After completing more than 15,000 independent observations as part of the total station testing, less than 1 percent of the data had to be rejected due to equipment failures or blunders.

The Model 100 system was also used for recording the base line observations. The software developed functions similar to the quad software by utilizing input error checking and feedback to the user during observations. Data sets are organized by unique file name and consist of instrument description, reflector description, from and to base points, meteorological data observations, distance measurements, instrument horizontal distance, base horizontal distance, and difference between instrument and base distances.

Each file constitutes one complete set of EDMI distance measurements over a given segment of the base line. After all observations are entered, the program applies all corrections, reduces corrected slope distance to horizontal distance, and computes the difference between the instrument's horizontal distance and the known base horizontal distance. Finally, files are saved to each of two floppy discs. With the exception of later printing a hard copy of the files, no further processing of observation data is needed.

The primary output of each file is the difference between EDMI length and base length. These values are used in the least squares adjustment program that determines the scale correction, constant correction, variance of unit weight, and standard errors of both scale and constant corrections for the respective EDMI.

DATA ANALYSIS

Data analysis was performed to determine the relationship between the capabilities of each instrument and the specifications for geodetic surveys as given by the FGCC (1984). Table 1 lists the specifications considered.

The following sources of information were used to determine which order and class requirements a particular instrument could satisfy:

1. Manufacturer's specifications.
2. Field books generated by the data processing systems.

When field books were used, the data under a particular category were summarized and the statistical properties of the mean value, standard deviation, and sometimes the standard deviation of the mean were computed. As an example, a total of eight horizontal angles were measured by three observers. Each observer measured each angle with 16 positions, direct and reverse. The standard deviation of the mean was then computed from this total set containing 384 observations (8×3×16).

The following definitions were used for the statistics:

The sample mean is

$$\bar{X} = \frac{1}{n} \sum_{i=1}^{n} X_i \tag{1}$$

The standard deviation of a single observation is

$$\sigma_X = \sqrt{\frac{1}{n-1} \sum_{i=1}^{n} (X_i - \bar{X})^2} \tag{2}$$

and the standard deviation of the mean,

$$\sigma_{\bar{X}} = \frac{\sigma_X}{\sqrt{n}} \tag{3}$$

where X_i is the ith observation and n is the number of observations.

Table 1.--Federal Geodetic Control Committee specifications for geodetic control surveys

		Order/Class				
		I	II/I	II/II	III/I	III/II
1. Network geometry						
Station spacing	T	15	10	5	0.5	0.5
not less than (km)	L	10	4	2	0.5	0.5
2. Instrumentation						
Theodolite, least	T	0.2"	0.2"	1.0"	1.0"	1.0"
count	L	0.2"	1.0"	1.0"	1.0"	1.0"
3. Field procedures						
3a.Directions						
Number of positions	T	16	16	12	4	2
	L	16	12	8	4	2
Standard deviation of mean not to	T	0.4"	0.5"	0.8"	1.2"	2.0"
exceed	L	0.4"	0.5"	0.8"	1.2"	2.0"
Rejection limit	T	4"	4"	5"	5"	5"
from mean	L	4"	5"	5"	5"	5"
3b.Reciprocal vertical angles						
No. of independent	T	3	3	2	2	2
observations D/R	L	3	3	2	2	2
Maximum spread	T	10"	10"	10"	10"	20"
	L	10"	10"	10"	10"	20"
3c.Infrared distances						
Minimum number of	T	-	10	10	10	10
readings	L	10	10	10	10	10
Maximum difference from mean of	T	-	5	5	10	10
observations (mm)	L	10	10	10	-	-
4. Office procedures						
Triangle closure average not to exceed	T	1.0"	1.2"	2.0"	3.0"	5.0"
5. Geodetic leveling field procedure		I	I/II	II/I	II/II	III
Maximum loop misclosure (mm)		$4\sqrt{k}$	$5\sqrt{k}$	$6\sqrt{k}$	$8\sqrt{k}$	$12\sqrt{k}$
for Corbin quad		2.8	3.5	4.2	5.6	8.5

T = triangulation; L = traverse

The means and standard deviations of all data sets were orginally computed with no rejection limits. Next, published rejection limits were included and new values computed. Due to the overall quality of the data, the incorporation of rejection limits made no significant difference in the results. The values calculated for each instrument tested are given in tables 3 through 8.

The overall accuracy of each instrument was also evaluated by processing the data with the HAVAGO adjustment program. This program, which is described in NOAA Technical Memorandum NOS NGS 17, "The HAVAGO three-dimensional adjustment program" (1979), runs on the HP1000 computer at NGS headquarters. The program outputs positional errors in three dimensions and residuals from each set of observations on a line's distance, azimuth, and vertical angle.

A comparison was made between each of the total station instruments and the base line values for the Corbin quad. The original network was observed with a Geodimeter 112 EDMI, Wild T-3 theodolite, and a Zeiss NI 002 level. The adjustment was run on the original data set and on each of the total stations by inputting estimated observational errors as specified by the individual manufacturer. To compare each of the instruments all errors were forced into the residuals (v) by holding the elevations fixed and setting the refraction to zero. This caused the residuals of the vertical angles to appear larger than they actually were, but it allowed a direct comparison between each of the instruments. The residuals were then used to compute the root-mean-square (rms) error of the distance, azimuth, and vertical angle of each instrument, where

$$rms = \sqrt{\frac{\sum_{i=1}^{n} v^2}{n}} \qquad (4)$$

RESULTS

Based on the HAVAGO output the horizontal positional errors (accuracies) of all the instruments, including the original base network, were at the 2 mm level. The vertical errors (accuracies) for each of the instruments, except the Lietz, was 1 mm. By running several iterations of the Lietz data set, the refraction values were found to be erratic. Further field testing indicated the instrument had a malfunctioning vertical compensator which was not revealed during the bench test. Due to time constraints it was not possible to make repairs and collect a new data set for evaluation. Therefore, no results on vertical angles or elevations are reported for the Lietz.

Table 2 compares the original network with each of the total stations, as summarized from the HAVAGO adjustment. Included for each instrument are the root-mean-square error and adjusted value of the distance, azimuth, and vertical angle on each leg of the Corbin quad.

These results from the HAVAGO adjustment show the ability of each of the total stations to perform very accurate observations. However, a direct comparison of the results of the field work and the major items in the standards and specifications (table 1) gives a more detailed look at an instrument's ability to perform a first-, second-, or third-order control survey. Tables 3 to 8 show the relationship between the capabilities of each

Table 2.--Corbin quad comparison

Instrument	rms	1-2	2-3	3-4	4-1
	Quad stations (standpoint to forepoint)				
Original network					
Distance (m)	0.0008	122.837	123.438	127.235	150.001
Azimuth	0.7"	46°16'06.6"	135°32'30.9"	214°12'39.0"	316°16'41.8"
Vertical angle	15.2"	89°33'46.6"	89°30'37.0"	90°25'31.1"	90°23'54.8"
Geodimeter					
Distance (m)	0.0008	122.837	123.438	127.233	150.001
azimuth	1.1"	46°16'03.3"	135°32'32.9"	214°12'52.5"	316°16'44.5"
Vertical angle	7.0"	89°33'31.8"	89°30'56.0"	90°25'41.2"	90°24'02.2"
Kern					
Distance (m)	0.0019	122.838	123.440	127.235	150.003
Azimuth	0.8"	46°16'05.1"	135°32'32.9"	214°12'49.9"	316°16'43.6"
Vertical angle	5.5"	89°33'30.2"	89°30'56.5"	90°25'37.1"	90°23'57.0"
Lietz					
Distance (m)	0.0015	122.838	123.439	127.234	150.002
Azimuth	0.8"	46°16'02.7"	135°32'33.6"	214°12'50.9"	316°16'46.1"
Vertical angle	-	-	-	-	-
Nikon					
Distance (m)	0.0016	122.838	123.439	127.234	150.002
Azimuth	0.7"	46°16'02.4	135°32'33.2"	214°12'52.2"	316°16'43.4"
Vertical angle	8.0"	89°33'34.7"	89°30'51.5"	90°25'42.3"	90°24'02.3"
Topcon					
Distance (m)	0.0017	122.836	123.438	127.234	150.001
Azimuth	0.8"	46°16'07.0"	135°32'32.4"	214°12'48.0"	316°16'43.2"
Vertical angle	7.4"	89°33'30.5"	89°30'52.1"	90°25'37.8"	90°23'56.1"
Wild					
Distance (m)	0.0009	122.838	123.439	127.234	150.002
Azimuth	0.8"	46°16'04.2"	135°32'33.9"	214°12'49.4"	316°16'44.2"
Vertical angle	5.8"	89°33'31.1"	89°30'56.1"	90°25'38.4"	90°23'58.7"

of the total stations and the FGCC standards and specifications (1984). Also given for each instrument are the results of the EDMI calibration and the manufacturer's specifications.

The test results for each of these instruments are listed as follows:

INSTRUMENT	TABLE
Geodimeter	3
Kern	4
Lietz	5
Nikon	6
Topcon	7
Wild	8

The values in each of these tables are those calculated by summarizing all the observations for that particular instrument, in each respective category. The results are also listed under the order and class which would be satisfied according to the FGCC standards and specifications.

Under the category Geodetic Leveling, the loop misclosure was computed by summing the difference of elevation (delta h function) around the quad. In other words, the elevations were determined by trigonometric levels.

It should be noted that these results were obtained by highly skilled technicians adhering to stringent procedures. Similar results may not be obtained under other conditions.

SUMMARY

The intent of this test was to establish the relationship between the capabilities of some of the new total station instruments and the Standards and Specifications for Geodetic Control Networks. To make this comparison each of the instruments was used in a series of observations on a test network previously established at the NGS Corbin facility. The observations from each instrument were then adjusted with the HAVAGO least squares program. The original data set used to establish the network was also adjusted with HAVAGO. A direct comparison was then made between the original network and each of the total stations. This comparison examined the three-dimensional positional errors and the root-mean-square of the adjusted distances, azimuths and vertical angles. The errors showed good correlation between each of the total stations and the original network except in the case of the Lietz instrument. This instrument was found to have a faulty vertical compensator, and the values for the vertical angles and elevations were erratic. Due to various constraints the FGCC did not allow the manufacturer to make the necessary repairs in time for further testing.

The next step in the evaluation was to compute the mean and standard deviations of various observation parameters and to compare them with the published specifications.

In horizontal directions the instruments showed full capability to perform to first- and second-order specifications. The distances were well within first-order standards, but their range limited their use to lower orders. The vertical angles also exceeded first-order standards. Combining the distances and vertical angles (delta h function) to perform trigonometric leveling yielded results in the second- and third-order geodetic leveling classification. However, the differences of elevation were not consistent at these accuracies, often falling below the FGCC specifications. This inconsistency was probably caused by atmospheric refraction and insufficient field procedures to minimize this error source.

The new technology used in the modern total stations has created a convenient field unit with many capabilities for fast, efficient operation and data transfer. When following proper procedures these instruments show full potential to perform geodetic quality horizontal surveys. Establishing geodetic quality elevations was less successful. It may be possible, however, to develop new techniques to take advantage of this potential.

ACKNOWLEDGMENTS

The testing and evaluation of these new instruments required a tremendous amount of data collection and processing to reduce the final conclusions to a few tables and paragraphs. Without the assistance of many talented people this effort would not have been possible. Therefore, I would like to express my thanks to Messrs. Klaus Drehman, Charles Glover, Orland Murray, Richard Wright and Mrs. Renee Shields of the National Geodetic Survey, and Mrs. Donna Tyson and Mr. Jeffrey Walker of the U.S. Army Engineer Topographic Laboratories.

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Table 3.--AGA Geotronics manufacturer's specifications

Model		Geodimeter 142
Serial number		48076
Configuration		Integral non-coaxial
Telescope		
Magnification		30X
Objective aperture		40 mm
Angulation		
Accuracy:	horizontal	1 "
	vertical	1 "
Least count		1 "
EDMI		
Range:	1 prism	2500 m
	3 prism	3600 m
	6 prism	4500 m
	8 prism	5500 m
Accuracy		± 2 mm + 3 ppm
Resolution		0.1 mm
Wavelength		0.910 nm
Modulation frequency		14985528 Hz

(continued)

Table 3.--Continued

Geodimeter 142 test results

		ORDER/CLASS				
		I	II/I	II/II	III/I	III/II
NETWORK GEOMETRY						
Station Spacing	T			5.5		
	L		5.5			
INSTRUMENTATION						
Theodolite, least count	T			1.0"		
	L		1.0"			
FIELD PROCEDURES						
Directions Standard deviation of mean not to exceed	T			.59		
	L			.59		
Rejection limit from mean	T	4"				
	L	4"				
Reciprocal Vertical Angles Maximum Spread	T	1.8"				
	L	1.8"				
Infrared Distances Maximum difference from mean of observations (mm)	T	-	* See EDMI Calibration sheet following			
	L	*				
OFFICE PROCEDURES						
Triangle Closure not to exceed average						4.1
GEODETIC LEVELING		I/I	I/II	II/I	II/II	III
Maximum loop misclosure (mm)		DID NOT MEET THIRD ORDER (11mm)				

T - Triangulation
L - Traverse

(continued)

Table 3.--Concluded

EDMI calibration
Corbin Calibration Base Line

Geodimeter Model 142 Serial No. 48076

Observations and least squares adjustment performed according to NOAA Technical Memorandum NOS NGS-10.

A priori input to least squares adjustment.......	±2 mm + 3 ppm
Scale correction................................	+3.40 ppm
Constant correction.............................	-0.6 mm
Variance of unit weight.........................	0.04
Standard error of scale correction..............	±0.45 ppm
Standard error of constant correction...........	±0.21 mm

Results of constant determination derived from least squares adjustment. These values were used in Corbin quad observation reductions.

Table 4.--Kern Swiss manufacturer's specifications

Model		E2
Serial number		325882
Configuration		modular
Telescope	DKM2-A	
Magnification		32X
Objective aperture		45 mm
Ambulation		
Accuracy:	horizontal	0.5"
	vertical	0.5"
Least count		1"
EDMI DM 503		
Range:	1 prism	3000 m
	3 prism	4500 m
	7 prism	5500 m
Accuracy		± 3 mm + 2 ppm
Resolution		1 mm
Wavelength		0.860 nm
Modulation frequency		14985400 Hz

(continued)

Table 4.--Continued

KERN E2 / DM 503 test results

		ORDER/CLASS				
		I	II/I	II/II	III/I	III/II
NETWORK GEOMETRY						
Station Spacing	T			5.5		
	L		5.5			
INSTRUMENTATION						
Theodolite, least count	T			1.0"		
	L		1.0"			
FIELD PROCEDURES						
Directions						
Standard deviation of mean not to exceed	T	0.35"				
	L	0.35"				
Rejection limit from mean	T	4"				
	L	4"				
Reciprocal Vertical Angles						
Maximum spread	T	1.6"				
	L	1.6"				
Infrared Distances						
Maximum difference from mean of observations (mm)	T	-	*See EDMI calibration sheet following			
	L	*				
OFFICE PROCEDURES						
Triangle Closure not to exceed average	T		1.1"			
GEODETIC LEVELING		I/I	I/II	II/I	II/II	III
Maximum loop misclosure (mm)					5.3	

T - Triangulation
L - Traverse

(continued)

Table 4.--Concluded

EDMI calibration
Corbin Calibration Base Line

Kern DM503 Serial No. 325882

Observations and least squares adjustment performed according to *NOAA Technical Memorandum* NOS NGS-10.

A priori input to least squares adjustment........	±3 mm + 2 ppm
Scale correction..................................	+3.65 ppm
Constant correction...............................	+0.7 mm
Variance of unit weight...........................	0.24
Standard error of scale correction................	±1.2 ppm
Standard error of constant correction.............	±0.67 mm

Results of constant determination derived from least squares adjustment. These values were used in Corbin quad observation reductions.

Table 5.--Lietz Sokkisha manufacturer's specifications

Model		SET 3
Serial number		77376
Configuration		Coaxial
Telescope		
Magnification		25X
Objective aperture		45 mm
Angulation		
Accuracy:	horizontal	5"
	vertical	5"
Least count		1"
EDMI		
Range:	1 prism	1000 m
	3 prism	1600 m
Accuracy		± 5 mm + 3 ppm
Resolution		1 mm
Wavelength		0.840 nm
Modulation frequency		14985445 Hz

(continued)

Table 5.--Continued
Lietz SET 3 test results

		ORDER/CLASS				
		I	II/I	II/II	III/I	III/II
NETWORK GEOMETRY						
Station Spacing	T				2.1	
	L			2.1		
INSTRUMENTATION						
Theodolite, least count	T			1"		
	L		1"			
FIELD PROCEDURES						
Directions Standard deviation of mean not to exceed	T			0.64"		
	L			0.64"		
Rejection limit from mean	T	4"				
	L	4"				
Reciprocal Vertical Angles Maximum Spread	T					
	L					
Infrared Distances Maximum difference from mean of observations (mm)	T	-	* See EDMI Calibration sheet following			
	L	*				
OFFICE PROCEDURES						
Triangle Closure not to exceed average				1.5"		
GEODETIC LEVELING		I/I	I/II	II/I	II/II	III
Maximum loop misclosure (mm)						

T - Triangulation
L - Traverse

(continued)

Table 5.--Concluded

EDMI calibration
Corbin Calibration Base Line

Lietz Model SET 3 Serial No. 77376

Observations and least squares adjustment performed according to <u>NOAA Technical Memorandum</u> NOS NGS-10.

A priori input to least squares adjustment.........	±5 mm + 3 ppm
Scale correction..................................	+4.3 ppm
Constant correction................................	+28.5 mm
Variance of unit weight...........................	0.02
Standard error of scale correction.................	±0.57 ppm
Standard error of constant correction..............	±0.32 mm

Results of constant determination derived from least squares adjustment. These values were used in Corbin quad observation reductions.

Table 6.--Nikon manufacturer's specifications

Model		DTM-1
Serial number		84011
Configuration		Coaxial
Telescope		
Magnification		30X
Objective aperture		45 mm
Angulation		
Accuracy:	horizontal	2"
	vertical	3"
Least count		1"
EDMI		
Range:	1 prism	1600 m
	3 prism	2300 m
Accuracy		± 5 mm + 5 ppm
Resolution		1 mm
Wavelength		0.820 nm
Modulation frequency		14972947 Hz

(continued)

Table 6.--Continued

NIKON DTM-1 test results

		ORDER/CLASS				
		I	II/I	II/II	III/I	III/II
NETWORK GEOMETRY						
Station Spacing	T				1.8	
	L				1.8	
INSTRUMENTATION						
Theodolite, least	T			1"		
count	L		1"			
FIELD PROCEDURES						
Directions						
Standard deviation	T			0.55"		
of mean not to	L			0.55"		
exceed						
Rejection limit	T	4"				
from mean	L	4"				
Reciprocal Vertical						
Angles	T	1.9"				
Maximum Spread	L	1.9"				
Infrared Distances						
Maximum difference	T	-	* See EDMI Calibration			
from mean of	L	*	sheet following			
observations (mm)						
OFFICE PROCEDURES						
Triangle Closure						
not to exceed				1.3"		
average						
GEODETIC LEVELING		I/II	I/II	II/I	II/II	III
Maximum loop						
misclosure (mm)						7.8

T - Triangulation
L - Traverse

(continued)

Table 6.--Concluded

EDMI calibration
Corbin Calibration Base Line

Nikon Model DTM-1 Serial No. 84011

Observations and least squares adjustment performed according to NOAA Technical Memorandum NOS NGS-10.

A priori input to least squares adjustment......	±5 mm + 5 ppm
Scale correction................................	0.00 ppm
Constant correction.............................	+63.8 mm
Variance of unit weight.........................	0.04
Standard error of scale correction..............	±0.014 ppm
Standard error of constant correction...........	±0.26 mm

Results of constant determination derived from least squares adjustment. These values were used in Corbin quad observation reductions.

Table 7.--Topcon manufacturer's specifications

Model		ET-1
Serial number		F30109
Configuration		Coaxial
Telescope		
Magnification		30X
Objective aperture		40 mm
Angulation		
Accuracy:	horizontal	2"
	vertical	3"
Least count		1"
EDMI		
Range:	1 prism	1400 m
	3 prism	2000 m
	9 prism	2600 m
Accuracy		± 5 mm + 5 ppm
Resolution		1 mm
Wavelength		0.840 nm
Modulation frequency		14985435 Hz

(continued)

Table 7.--Continued

Topcon ET-1 test results

		ORDER/CLASS				
		I	II/I	II/II	III/I	III/II
NETWORK GEOMETRY						
Station Spacing	T				2.5	
	L			2.5		
INSTRUMENTATION						
Theodolite, least count	T			1"		
	L		1"			
FIELD PROCEDURES						
Directions Standard deviation of mean not to exceed	T			0.57"		
	L			0.57"		
Rejection limit from mean	T			5"		
	L		5"			
Reciprocal Vertical Angles						
Maximum spread	T	1.6"				
	L	1.6"				
Infrared Distances Maximum difference from mean of observations (mm)	T	-	* See EDMI Calibration sheet following			
	L	*				
OFFICE PROCEDURES						
Triangle Closure not to exceed average	T			1.5"		
	L			1.5"		
GEODETIC LEVELING		I/I	I/II	II/I	II/II	III
Maximum loop misclosure (mm)						7.1

T - Triangulation
L - Traverse

(continued)

Table 7.--Concluded

EDMI calibration
Corbin Calibration Base Line

Topcon ET-1 Serial No. F30109

Observations and least squares adjustment performed according to NOAA Technical Memorandum NOS NGS-10.

A priori input to least squares adjustment........	±5 mm + 5 ppm
Scale correction..................................	-0.90 ppm
Constant correction...............................	+0.2 mm
Variance of unit weight...........................	0.02 (unitless)
Standard error of scale correction................	±0.58 ppm
Standard error of constant correction.............	±0.30 mm

Results of constant determination derived from least squares adjustment. These values were used in Corbin quad observations reductions.

Table 8.--Wild Heerbrugg manufacturer's specifications

Model		T2000
Serial number		308310
Configuration		Modular
Telescope	T2	
Magnification		32X
Objective aperture		42 mm
Angulation		
Accuracy:	horizontal	0.5"
	vertical	0.5"
Least count		0.1"
EDMI	DI5	
Range:	1 prism	2500 m
	3 prism	3500 m
	7 prism	4500 m
	11 prism	5000 m
Accuracy		± 3 mm + 2 ppm
Resolution		1 mm
Wavelength		0.845 nm
Modulation frequency		4870255 Hz

(continued)

Table 8.--Continued

WILD T2000/DI5 test results

		ORDER/CLASS				
		I	II/I	II/II	III/I	III/II
NETWORK GEOMETRY						
Station Spacing	T			7.0		
	L		7.0			
INSTRUMENTATION						
Theodolite, least count	T	0.1"				
	L	0.1"				
FIELD PROCEDURES						
Directions						
Standard deviation of mean not to exceed	T	0.33"				
	L	0.33"				
Rejection limit from mean	T	4"				
	L	4"				
Reciprocal Vertical Angles						
Maximum spread	T	1.8"				
	L	1.8"				
Infrared Distances						
Maximum difference from mean of observations (mm)	T	-	* See EDMI Calibration sheet following			
	L	*				
OFFICE PROCEDURES						
Triangle Closure not to exceed average	T			1.5"		
	L			1.5"		
GEODETIC LEVELING		I/I	I/II	II/I	II/II	III
Maximum loop misclosure (mm)					5.4	

T - Triangulation
L - Traverse

(continued)

Table 8.--Concluded

EDMI calibration
Corbin Calibration Base Line

Wild DI5 Serial No. 50171

Observations and least squares adjustment performed according to NOAA Technical Memorandum NOS NGS-10.

A priori input to least squares adjustment..........	±3 mm + 2 ppm
Scale correction....................................	+3.76 ppm
Constant correction.................................	+32.7 mm
Variance of unit weight.............................	0.80 (unitless)
Standard error of scale correction..................	±2.38 ppm
Standard error of constant correction...............	±1.32 mm

Results of constant determination derived from least squares adjustment. These values were used in Corbin quad observations reductions.

APPENDIX A.--CORBIN CALIBRATION BASE LINE DATA

US DEPARTMENT OF COMMERCE - NOAA
NOS - NATIONAL GEODETIC SURVEY
ROCKVILLE MD 20852 - NOVEMBER 10, 1982

CALIBRATION BASE LINE DATA
BASE LINE DESIGNATION: CORBIN
PROJECT ACCESSION NUMBER: G15767

QUAD: N387732
VIRGINIA
CAROLINE COUNTY

LIST OF ADJUSTED DISTANCES (AUGUST 2, 1982)

FROM STATION	ELEV.(M)	TO STATION	ELEV.(M)	ADJ. DIST.(M) HORIZONTAL	ADJ. DIST.(M) MARK - MARK	STD. ERROR(MM)
0	66.720	50	66.910	50.0058	50.0062	0.0
0	66.720	300	65.516	300.0016	300.0040	0.2
0	66.720	500	64.055	499.9956	500.0027	0.2
0	66.720	1000	64.944	1000.0236	1000.0252	0.4
50	66.910	300	65.516	249.9958	249.9997	0.2
50	66.910	500	64.055	449.9898	449.9989	0.2
50	66.910	1000	64.944	950.0178	950.0199	0.4
300	65.516	500	64.055	199.9940	199.9994	0.1
300	65.516	1000	64.944	700.0220	700.0222	0.4
500	64.055	1000	64.944	500.0279	500.0287	0.4

DESCRIPTION OF CORBIN BASE LINE
YEAR MEASURED: 1976 - 1982
CHIEF OF PARTY: VARIOUS

THE BASE LINE IS LOCATED APPROXIMATELY 10 MILES NORTH OF BOWLING GREEN, NINE MILES SOUTH-SOUTHEAST OF FREDERICKSBURG AND 0.6 MILE EAST OF CORBIN, VIRGINIA. THE BASE LINE IS SITUATED ON U.S. GOVERNMENT PROPERTY AT THE SITE OF THE FREDERICKSBURG GEOMAGNETIC CENTER AND THE OFFICE OF THE INSTRUMENT AND EQUIPMENT BRANCH OF THE NATIONAL GEODETIC SURVEY.

TO REACH THE INSTRUMENT AND EQUIPMENT BRANCH OFFICE OF THE NATIONAL GEODETIC SURVEY FROM THE JUNCTION OF U.S. HIGHWAY 17 SOUTH BYPASS AND VIRGINIA STATE HIGHWAY 2 WHICH IS APPROXIMATELY 6.5 MILES SOUTH OF FREDERICKSBURG, GO SOUTH ON STATE HIGHWAY 2 FOR 2.35 MILES TO A STORE ON THE LEFT AND A SIDE ROAD LEFT, JUST BEYOND THE STORE IN THE SMALL SETTLEMENT OF CORBIN. TURN LEFT AND GO SOUTHEAST AND EAST ON STATE HIGHWAY 610 FOR 0.4 MILE TO WHERE THE HIGHWAY BEARS SHARP LEFT AND A SECONDARY ROAD (BURMA ROAD) GOES STRAIGHT AHEAD. CONTINUE EAST ON BURMA ROAD (U.S. PROPERTY) FOR 0.3 MILE TO A CIRCLE DRIVEWAY ON THE LEFT. TURN LEFT AND GO NORTH AND EAST ON THE DRIVEWAY FOR 0.1 MILE TO THE OFFICE OF THE INSTRUMENT AND EQUIPMENT BRANCH ON THE LEFT WHERE INFORMATION CONCERNING THE LOCATION OF THE BASE LINE CAN BE OBTAINED.

THE HORIZONTAL LENGTH OF THE BASE LINE IS 1000 METERS. IT IS MONUMENTED AT 0M, 50M, 300M, 500M, 925M, AND 1000M. EACH MONUMENT IS OF POURED CONCRETE SET INTO A DEPTH OF FIVE FEET. THE MONUMENTS PROTRUDE TWO INCHES ABOVE THE GROUND SURFACE AND TAPER FROM 18 INCHES IN DIAMETER AT THE BOTTOM TO 10 INCHES SQUARE AT THE TOP. THERE IS A BRONZE DISK SET IN THE TOP OF EACH CONCRETE MONUMENT AND THE EXACT POINT IS A 0.4 MILLIMETER DIAMETER DRILLED HOLE IN THE CENTER OF THE DISKS.

EACH MONUMENT HAS OVER IT A PERMANENT FOUR LEGGED ANODIZED ALUMINUM INSTRUMENT STAND. THE STANDS ARE FITTED WITH 12 INCH CIRCULAR TRIBRACHS WITH A 3/4 INCH DIAMETER HOLE IN THEIR CENTER. THE TRIBRACHS ARE ADJUSTABLE FOR COLLIMATING PURPOSES. EACH POINT ON THE BASE LINE IS VISIBLE FROM ANY OTHER POINT ON THE BASE. EACH POINT CAN BE DRIVEN TO IN ANY TWO-WHEEL DRIVE VEHICLE IN ANY WEATHER.

CORBIN BASE LINE WAS ESTABLISHED PRIMARILY FOR USE BY THE NATIONAL GEODETIC SURVEY FOR THE CALIBRATION AND TESTING OF ELECTRONIC DISTANCE MEASURING INSTRUMENTS. ARRANGEMENTS FOR USE OF THE BASE LINE CAN BE MADE BY CONTACTING: WILLIAM V. MAST OR CHARLES C. GLOVER, INSTRUMENT AND EQUIPMENT BRANCH, NATIONAL GEODETIC SURVEY, NATIONAL OCEAN SURVEY, NOAA, P.O. BOX 1, CORBIN, VIRGINIA 22446. PHONE: COMMERCIAL NO. (703) 373-7605 OR FTS NO. (925) 0243-0244.

APPENDIX B.--EXAMPLE OUTPUT OF DATA LOGGING PROGRAMS

CORBIN CALIBRATION BASELINE OBSERVATIONS

FILENAME:K503-1 DATE:10/01/85

EDMI		REFLECTOR	SCALES
COMPANY:KERN	LIGHT:INFRARED	TYPE:KERN	PPM TEMP:C
MODEL:DM503	GROUP VEL:105.80	S/N:1	WET/DRY TEMP:F
S/N: 325882	PSET INDEX:281.94	CONST: 0.0000	PRESSURE:FT
MOUNT:THEO	INST.CONST: 0.0000	NO.SHOWN: 1	
S/N: 345381	REJ.TOL: 0.0050m		OBS:KL REC:CCG
WV: 0.8600 ym	FM: 14985400 Hz		

EDMI STATION		REFLECTOR STATION		
CORBIN BASE	0	CORBIN BASE	50	HUMIDITY
HT ABOVE TRI:	0.2370	HT ABOVE TRI:	0.2970	D/B TEMP: 74.0
HT OF STAND:	1.8060	HT OF STAND:	1.1560	W/B TEMP: 66.0
ELEV OF MARK:	66.7203	ELEV OF MARK:	66.9106	H CORR: 0.7
ELEV EDMI:	68.7633	ELEV OF REFL:	68.3636	SETS OF OBS: 4

START TIME:	113126	113553	113938	114310
END TIME:	113353	113802	114136	114511
1	50.005	49.857	50.158	50.008
2	50.009	49.856	50.157	50.007
3	50.010	49.858	50.157	50.007
4	50.009	49.857	50.158	50.007
5	50.010	49.857	50.158	50.008
6	50.010	49.857	50.157	50.007
7	50.010	49.857	50.159	50.007
8	50.011	49.857	50.157	50.007
9	50.010	49.857	50.157	50.007
10	50.009	49.858	50.157	50.007
MN SLP DIST:	50.0093	49.8571	50.1575	50.0072
REFL ECC:	0.0000	0.1500	-0.1500	0.0000
SUM:	50.0093	50.0071	50.0075	50.0072
REFL CONST:	0.0000	0.0000	0.0000	0.0000
R.I. CORR:	0.0006	0.0006	0.0006	0.0006
CORR SL DIST:	50.0099	50.0077	50.0081	50.0078
MET DATA:	TEMP/PRES	TEMP/PRES.	TEMP/PRES	TEMP/PRES
EDMI BEGIN:	22.7 /1060.0	23.3 /1060.0	23.4 /1060.0	24.0 /1060.0
REFL BEGIN:	22.0 /1040.0	22.3 /1035.0	22.5 /1035.0	22.8 /1040.0
EDMI END:	22.8 /1060.0	23.2 /1060.0	24.0 /1060.0	24.2 /1060.0
REFL END:	22.6 /1040.0	22.9 /1035.0	23.4 /1040.0	22.4 /1040.0
MEAN:	22.53 /1050.0	22.93 /1047.5	23.33 /1048.8	23.35 /1050.0
MN PRES mmHG:	758.0	758.1	758.1	758.0

MN CORR SL DIST: 50.0084

EDMI HOZ DIST: 50.0068
BASE HOZ DIST: 50.0058
DIF(EDMI-BASE): 0.0010

REMARKS:NONE

TOTAL STATIONS TEST - FIELDBOOK OF OBSERVATIONS

FILENAME: QWIL1 DATE:12/05/85

INSTRUMENT INFORMATION

MANUFACTURER: WILD	EDMI MODEL NAME: DI5
MODEL: T2000	SERIAL NUMBER: 50171
SERIAL NUMBER: 308310	EDMI OFFSET CONST: 0.0320

TEMP & PRES SCALE UNITS	PERSONNEL
PPM TEMP SCALE: C	OBSERVER: CCG
WET/DRY TEMP SCALE: F	RECORDER: KD
PRESSURE SCALE: FT	

STANDPOINT INFORMATION

SPN: 4	MARK ELEVATION: 67.66600
NAME: CORBIN QUAD 4	HT OF TRI ABOVE MK: 1.6132
	HT OF INST ABOVE TRI: 0.2338
	ELEV OF INST: 69.51300

3 FOREPOINTS OBSERVED WX START:00021 WX END:00020

FOREPOINT NO. 1 INFORMATION

SPN: 1	MARK ELEVATION: 66.62160
NAME: CORBIN QUAD 1	HT OF TRI ABOVE MK: 1.5153
REFL TYPE: HUTSON	HT OF REFL ABOVE TRI: 0.1768
REFL S/N: 33-85	
REFL OFFSET CONST: -.0531	ELEV OF REFL: 68.31370
NO. PRISMS SHN: 1	

FOREPOINT NO. 2 INFORMATION

SPN: 2	MARK ELEVATION: 67.57140
NAME: CORBIN QUAD 2	HT OF TRI ABOVE MK: 1.5370
REFL TYPE: HUTSON	HT.OF REFL ABOVE TRI: 0.1786
REFL S/N: 35-85	
REFL OFFSET CONST: -.0530	ELEV OF REFL: 69.28700
NO. PRISMS SHN: 1	

FOREPOINT NO. 3 INFORMATION

SPN: 3	MARK ELEVATION: 68.61040
NAME: CORBIN QUAD 3	HT OF TRI ABOVE MK: 1.6191
REFL TYPE: HUTSON	HT OF REFL ABOVE TRI: 0.1800
REFL S/N: 34-85	
REFL OFFSET CONST: -.0538	ELEV OF REFL: 70.40950
NO. PRISMS SHN: 1	

```
FILENAME: QWIL1                                                              DATE:12/05/85
*****************************************************************************************
                                 HORIZONTAL DIRECTIONS
*****************************************************************************************
STANDPOINT: CORBIN QUAD 4
-----------------------------------------------------------------------------------------
 POS *      FOREPOINT        * D/R * OBS'D DIR * COL  * DIRECTION *    TIME
*****************************************************************************************
  1  *                       *     *(DDD.MMSSS)*(SS.S)*(DDD.MMSSS)* START:10:30
     * CORBIN QUAD 1         *  D  *   0.00200 *      *           * END:  10:39
     *                       *  R  * 180.00196 * +0.4 *           *
-----------------------------------------------------------------------------------------
     * CORBIN QUAD 2         *  D  *  39.18561 *      *           *
     *                       *  R  * 219.18555 * +0.6 *  39.18360 *
-----------------------------------------------------------------------------------------
     * CORBIN QUAD 3         *  D  *  77.56231 *      *           *
     *                       *  R  * 257.56227 * +0.4 *  77.56031 *
-----------------------------------------------------------------------------------------
REMARKS:
PERFECT OBSERVING CONDITIONS-OBS TOP TGT @ DIR AND BOT TGT @ REV
*****************************************************************************************
  2  *                       *     *(DDD.MMSSS)*(SS.S)*(DDD.MMSSS)* START:10:41
     * CORBIN QUAD 1         *  D  *  11.00220 *      *           * END:  10:48
     *                       *  R  * 191.00199 * +2.1 *           *
-----------------------------------------------------------------------------------------
     * CORBIN QUAD 2         *  D  *  50.18571 *      *           *
     *                       *  R  * 230.18566 * +0.5 *  39.18359 *
-----------------------------------------------------------------------------------------
     * CORBIN QUAD 3         *  D  *  88.56259 *      *           *
     *                       *  R  * 268.56248 * +1.1 *  77.56044 *
-----------------------------------------------------------------------------------------
REMARKS:
NONE
*****************************************************************************************
  3  *                       *     *(DDD.MMSSS)*(SS.S)*(DDD.MMSSS)* START:10:48
     * CORBIN QUAD 1         *  D  *  22.00250 *      *           * END:  10:55
     *                       *  R  * 202.00257 * -0.7 *           *
-----------------------------------------------------------------------------------------
     * CORBIN QUAD 2         *  D  *  61.19019 *      *           *
     *                       *  R  * 241.19015 * +0.4 *  39.18364 *
-----------------------------------------------------------------------------------------
     * CORBIN QUAD 3         *  D  *  99.56291 *      *           *
     *                       *  R  * 279.56288 * +0.3 *  77.56036 *
-----------------------------------------------------------------------------------------
REMARKS:
NONE
*****************************************************************************************
  4  *                       *     *(DDD.MMSSS)*(SS.S)*(DDD.MMSSS)* START:10:55
     * CORBIN QUAD 1         *  D  *  33.00321 *      *           * END:  11:01
     *                       *  R  * 213.00300 * +2.1 *           *
-----------------------------------------------------------------------------------------
     * CORBIN QUAD 2         *  D  *  72.19066 *      *           *
     *                       *  R  * 252.19069 * -0.3 *  39.18357 *
-----------------------------------------------------------------------------------------
     * CORBIN QUAD 3         *  D  * 110.56362 *      *           *
     *                       *  R  * 290.56343 * +1.9 *  77.56042 *
-----------------------------------------------------------------------------------------
REMARKS:
GPS VEHICLE WITH MOTOR RUNNING CAUSES SCINTILLATION ON LINE TO CQ3
*****************************************************************************************
```

TOTAL STATIONS TEST - FIELDBOOK OF OBSERVATIONS

FILENAME: QWIL1 DATE:12/05/85

ABSTRACT OF HORIZONTAL DIRECTIONS

STANDPOINT: CORBIN QUAD 4

FOREPOINTS OBSERVED

POS	(INITIAL) CORBIN QUAD 1 (DDD.MMSSS)	CORBIN QUAD 2 (DDD.MMSSS)	CORBIN QUAD 3 (DDD.MMSSS)
1	000.00000	39.18360	77.56031
2	000.00000	39.18359	77.56044
3	000.00000	39.18364	77.56036
4	000.00000	39.18357	77.56042
5	000.00000	39.18350	77.56034
6	000.00000	39.18350	77.56035
7	000.00000	39.18350	77.56027
8	000.00000	39.18346	77.56013
9	000.00000	39.18345	77.56034
10	000.00000	39.18358	77.56037
11	000.00000	39.18354	77.56006
12	000.00000	39.18353	77.56028
13	000.00000	39.18348	77.56024
14	000.00000	39.18374	77.56034
15	000.00000	39.18361	77.56051
16	000.00000	39.18353	77.56029

MEAN DIRECTION	39.183549	77.560313
STANDARD DEVIATION	0.000075	0.000110

TOTAL STATIONS TEST - FIELDBOOK OF OBSERVATIONS

FILENAME: QWIL1 DATE:12/05/85

FIELDBOOK & ABS OF ZENITH DISTANCES

STANDPOINT: CORBIN QUAD 4 * ELEV: 69.51300

POS	FOREPOINT	D/R	OBS'D ZD	SUM D/R	CORR'D ZD	TIME
1			DDD.MMSSS	DDD.MMSSS	DDD.MMSSS	10:30
	CORBIN QUAD 1	D	90.28234			
	EL RFL: 68.31370	R	269.33203	360.01437	90.27316	
	CORBIN QUAD 2	D	90.04470			
	EL RFL: 69.28700	R	269.56359	360.01229	90.04056	
	CORBIN QUAD 3	D	89.36492			
	EL RFL: 70.40950	R	270.25131	360.02023	89.35481	

REMARKS:
PERFECT OBSERVING CONDITIONS-OBS TOP TGT @ DIR AND BOT TGT @ REV

POS	FOREPOINT	D/R	OBS'D ZD	SUM D/R	CORR'D ZD	TIME
2			DDD.MMSSS	DDD.MMSSS	DDD.MMSSS	10:41
	CORBIN QUAD 1	D	90.28243			
	EL RFL: 68.31370	R	269.33196	360.01439	90.27324	
	CORBIN QUAD 2	D	90.04475			
	EL RFL: 69.28700	R	269.56384	360.01259	90.04046	
	CORBIN QUAD 3	D	89.36500			
	EL RFL: 70.40950	R	270.25158	360.02058	89.35471	

REMARKS:
NONE

POS	FOREPOINT	D/R	OBS'D ZD	SUM D/R	CORR'D ZD	TIME
3			DDD.MMSSS	DDD.MMSSS	DDD.MMSSS	10:48
	CORBIN QUAD 1	D	90.28233			
	EL RFL: 68.31370	R	269.33209	360.01442	90.27312	
	CORBIN QUAD 2	D	90.04453			
	EL RFL: 69.28700	R	269.56349	360.01202	90.04052	
	CORBIN QUAD 3	D	89.36508			
	EL RFL: 70.40950	R	270.25139	360.02047	89.35485	

REMARKS:
NONE

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FILENAME: QWIL1 DATE: 12/05/85

MEAN CORRECTED ZENITH DISTANCES

STANDPOINT: CORBIN QUAD 4

FOREPOINTS OBSERVED

POS	CORBIN QUAD 1	CORBIN QUAD 2	CORBIN QUAD 3
	DDD.MMSSS	DDD.MMSSS	DDD.MMSSS
1	90.27316	90.04056	89.35481
2	90.27324	90.04046	89.35471
3	90.27312	90.04052	89.35485
4	90.27330	90.04071	89.35467
5	90.27324	90.04060	89.35489
6	90.27324	90.04057	89.35476
7	90.27330	90.04069	89.35469
8	90.27337	90.04093	89.35468
9	90.27333	90.04066	89.35500
10	90.27319	90.04052	89.35493
11	90.27329	90.04057	89.35470
12	90.27342	90.04068	89.35486
13	90.27327	90.04046	89.35478
14	90.27328	90.04051	89.35491
15	90.27324	90.04067	89.35494
16	90.27324	90.04056	89.35475
MEAN:	90.27326	90.04060	89.35481
STD DEV:	0.00008	0.00012	0.00011

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FILENAME: QWIL1                                                          DATE: 12/05/85
****************************************************************************************
                          SUMMARY OF CORRECTED SLOPE DISTANCES
****************************************************************************************
STANDPOINT: CORBIN QUAD 4    * OBS: CCB  REC: KD   * WX-BEGIN: 00021  END: 00020
----------------------------------------------------------------------------------------
TEMP-WET:  33.5  DRY:  37.0 * HUMIDITY CORR: 0.2 * EDMI CONST: 0.0320
****************************************************************************************
 POS  1 *            (BEGIN)              *              (END)
========================================================================================
         *  TIME       TEMP      PRES     *   TIME       TEMP       PRES
----------------------------------------------------------------------------------------
         *  10:30       3.8       870     *   10:39       4.0       870
========================================================================================
     FOREPOINT      * D/R * OBS S/D   * MN OBS'D *  PPM  * RI COR * CORR'D S/D
========================================================================================
CORBIN QUAD 1       *  D  * 150.0260 *            *       *        *
REFL CONST: -.0531  *  R  * 150.0250 * 150.0255 *  -8.8 * -.0013 * 150.0039
----------------------------------------------------------------------------------------
CORBIN QUAD 2       *  D  * 193.9150 *            *       *        *
REFL CONST: -.0530  *  R  * 193.9150 * 193.9150 *  -8.8 * -.0017 * 193.8931
----------------------------------------------------------------------------------------
CORBIN QUAD 3       *  D  * 127.2560 *            *       *        *
REFL CONST: -.0538  *  R  * 127.2560 * 127.2560 *  -8.8 * -.0011 * 127.2339
----------------------------------------------------------------------------------------
REMARKS:
PERFECT OBSERVING CONDITIONS-OBS TOP TGT @ DIR AND BOT TGT @ REV
****************************************************************************************
 POS  2 *            (BEGIN)              *              (END)
========================================================================================
         *  TIME       TEMP      PRES     *   TIME       TEMP       PRES
----------------------------------------------------------------------------------------
         *  10:41       4.1       870     *   10:48       3.9       870
========================================================================================
     FOREPOINT      * D/R * OBS S/D   * MN OBS'D *  PPM  * RI COR * CORR'D S/D
========================================================================================
CORBIN QUAD 1       *  D  * 150.0260 *            *       *        *
REFL CONST: -.0531  *  R  * 150.0250 * 150.0255 *  -8.7 * -.0013 * 150.0039
----------------------------------------------------------------------------------------
CORBIN QUAD 2       *  D  * 193.9150 *            *       *        *
REFL CONST: -.0530  *  R  * 193.9140 * 193.9145 *  -8.7 * -.0017 * 193.8926
----------------------------------------------------------------------------------------
CORBIN QUAD 3       *  D  * 127.2570 *            *       *        *
REFL CONST: -.0538  *  R  * 127.2550 * 127.2560 *  -8.7 * -.0011 * 127.2339
----------------------------------------------------------------------------------------
REMARKS:
NONE
****************************************************************************************

                                      PAGE  1
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FILENAME: QWIL1 DATE: 12/05/85

MEAN CORRECTED SLOPE DISTANCES

STANDPOINT: CORBIN QUAD 4

FOREPOINTS OBSERVED

POS	CORBIN QUAD 1	CORBIN QUAD 2	CORBIN QUAD 3
1	150.0039	193.8931	127.2339
2	150.0039	193.8926	127.2339
3	150.0029	193.8931	127.2339
4	150.0049	193.8922	127.2334
5	150.0040	193.8927	127.2329
6	150.0035	193.8922	127.2335
7	150.0040	193.8922	127.2350
8	150.0040	193.8928	127.2340
9	150.0047	193.8921	127.2337
10	150.0034	193.8927	127.2343
11	150.0038	193.8917	127.2338
12	150.0033	193.8916	127.2337
13	150.0048	193.8926	127.2337
14	150.0048	193.8917	127.2333
15	150.0048	193.8932	127.2338
16	150.0033	193.8922	127.2343
MEAN:	150.0040	193.8924	127.2338
STD DEV:	0.0006	0.0005	0.0005
HOZ DIST:	149.9992	193.8923	127.2306
GEO DIST:	149.9976	193.8902	127.2292

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TOTAL STATIONS TEST - FIELDBOOK OF OBSERVATIONS

FILENAME: QWIL1 DATE:12/05/85

FIELDBOOK OF ELEVATION DIFFERENCES

STANDPOINT: CORBIN QUAD 4 * EL EDM: 69.51300 * TIME-BGN:10:30 END:14:14

POS	FOREPOINT	D/R	OBS'D EL DIFF	MN D/R OBS'D	KWN EL DIFF
1					
	CORBIN QUAD 1	D	-1.237		
	EL RFL: 68.31370	R	-1.162	-1.1995	-1.19930
	CORBIN QUAD 2	D	-0.267		
	EL RFL: 69.28700	R	-0.189	-0.2280	-0.22600
	CORBIN QUAD 3	D	0.859		
	EL RFL: 70.40950	R	0.935	0.8970	0.89650

REMARKS:
PERFECT OBSERVING CONDITIONS-OBS TOP TGT @ DIR AND BOT TGT @ REV

POS	FOREPOINT	D/R	OBS'D EL DIFF	MN D/R OBS'D	KWN EL DIFF
2					
	CORBIN QUAD 1	D	-1.238		
	EL RFL: 68.31370	R	-1.162	-1.2000	-1.19930
	CORBIN QUAD 2	D	-0.267		
	EL RFL: 69.28700	R	-0.187	-0.2270	-0.22600
	CORBIN QUAD 3	D	0.859		
	EL RFL: 70.40950	R	0.936	0.8975	0.89650

REMARKS:
NONE

POS	FOREPOINT	D/R	OBS'D EL DIFF	MN D/R OBS'D	KWN EL DIFF
3					
	CORBIN QUAD 1	D	-1.241		
	EL RFL: 68.31370	R	-1.162	-1.2015	-1.19930
	CORBIN QUAD 2	D	-0.265		
	EL RFL: 69.28700	R	-0.190	-0.2275	-0.22600
	CORBIN QUAD 3	D	0.858		
	EL RFL: 70.40950	R	0.935	0.8965	0.89650

REMARKS:
NONE

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TOTAL STATIONS TEST - FIELDBOOK OF OBSERVATIONS

FILENAME: GWIL1 DATE:12/05/85

FIELDBOOK OF ELEVATION DIFFERENCES

STANDPOINT: CORBIN QUAD 4 * EL EDM: 69.51300 * TIME-BGN:10:30 END:14:14

FOREPOINTS OBSERVED

	CORBIN QUAD 1		CORBIN QUAD 2		CORBIN QUAD 3	
	EL RFL:	68.31370	EL RFL:	69.28700	EL RFL:	70.40950
KWN	EL DIF:	-1.19930	EL DIF:	-0.22600	EL DIF:	0.89650
POS	MN OBSD (meters)	OBS-KWN (mm)	MN OBSD (meters)	OBS-KWN (mm)	MN OBSD (meters)	OBS-KWN (mm)
1	-1.1995	-0.2	-0.2280	-2.0	0.8970	0.5
2	-1.2000	-0.7	-0.2270	-1.0	0.8975	1.0
3	-1.2015	-2.2	-0.2275	-1.5	0.8965	0.0
4	-1.2005	-1.2	-0.2295	-3.5	0.8980	1.5
5	-1.2005	-1.2	-0.2285	-2.5	0.8965	0.0
6	-1.2005	-1.2	-0.2280	-2.0	0.8970	0.5
7	-1.2010	-1.7	-0.2295	-3.5	0.8975	1.0
8	-1.2005	-1.2	-0.2315	-5.5	0.8975	1.0
9	-1.2010	-1.7	-0.2285	-2.5	0.8960	-0.5
10	-1.1995	-0.2	-0.2275	-1.5	0.8960	-0.5
11	-1.2010	-1.7	-0.2280	-2.0	0.8980	1.5
12	-1.2005	-1.2	-0.2290	-3.0	0.8970	0.5
13	-1.2000	-0.7	-0.2275	-1.5	0.8970	0.5
14	-1.2005	-1.2	-0.2275	-1.5	0.8965	0.0
15	-1.2005	-1.2	-0.2295	-3.5	0.8960	-0.5
16	-1.2005	-1.2	-0.2280	-2.0	0.8975	1.0

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